

CLAIMS

What is claimed is:

1. A hydrogel particle-forming apparatus comprising:
 - (a) a housing having a wall and a cavity,
 - (b) at least one inlet port in the wall of the housing for introducing hydrogel-forming suspension into the housing cavity,
 - (c) an extrusion die having a face with one or a plurality of extrusion holes through which the hydrogel-forming suspension can be extruded from the housing cavity,
 - (d) a cutting assembly comprising at least one cutting blade that cuts the hydrogel particle-forming suspension into individual hydrogel particles when the suspension exits the extrusion holes as the cutting blade moves across each extrusion hole, wherein the cutting blade is in close proximity with the face of the extrusion die and moves in a linear, rotating, or reciprocating manner,
 - (e) optionally, a drive shaft contained within the housing cavity,
 - (f) optionally, one or a plurality of bearings within the housing cavity supporting the drive shaft,
 - (g) optionally, one or a plurality of seals contacting the drive shaft,
 - (h) optionally a mixing device within the housing cavity for mixing the hydrogel-forming suspension,
 - (i) optionally, one or a plurality of radial slots in the housing cavity for distributing the hydrogel-forming suspension, and
 - (j) optionally, an internal pump within the housing cavity for moving the hydrogel-forming suspension to the extrusion die.
2. A hydrogel particle-forming system comprising:
 - (a) at least one feed station for containing a hydrogel-forming suspension,
 - (b) the hydrogel particle-forming apparatus of Claim 1,
 - (c) a metering device having transfer lines connected to the feed station and to the hydrogel particle-forming apparatus for receiving hydrogel-forming suspension from

- the feed station and delivering it to the hydrogel particle-forming apparatus, and
- (d) a quench station containing a quench fluid,
wherein the hydrogel particle-forming apparatus is at least partially
- 5 submerged in the quench fluid and the hydrogel-forming suspension is extruded into the quench fluid from the hydrogel particle-forming apparatus to form hydrogel particles.
3. The system of Claim 2 wherein the metering device is a volumetric metering pump.
- 10 4. The system of Claim 2 wherein the cutting assembly is rotatably mounted and further comprises a plurality of mixing blades for mixing the quench fluid as the cutting assembly rotates in the quench fluid.
5. The system of Claim 2 further comprising at least one mixing device for mixing components before they are introduced into the hydrogel
- 15 particle-forming apparatus.
6. The system of Claim 5 wherein the mixing device is located in the feed station.
7. The system of Claim 5 wherein the mixing device is located in a transfer line of the metering device.
- 20 8. The system of Claim 2 wherein the quench station further comprises an inclined surface for collecting the hydrogel particles and at least one additional collection reservoir for collecting the quench fluid as the quench fluid exits the quench station, wherein the quench fluid is recycled back from the additional collection reservoir into the quench
- 25 station after the hydrogel particles are collected on the inclined surface.
9. The system of Claim 2 further comprising at least one additional feed station for containing a quench fluid or an additive or both and a metering device having transfer lines connected to the additional feed station and to the hydrogel particle-forming apparatus for receiving
- 30 the quench fluid or the additive from the additional feed station and delivering it to the hydrogel particle-forming apparatus.
10. The apparatus of Claim 1 wherein the drive shaft is rotatably mounted in the housing cavity.
11. The system of Claim 2 wherein the drive shaft is rotatably
- 35 mounted in the housing cavity.
12. The apparatus of Claim 1 wherein the mixing device within the housing cavity is driven by the drive shaft.

13. The system of Claim 2 wherein the mixing device within the housing cavity is driven by the drive shaft.

14. The apparatus of Claim 1 wherein the extrusion die contains a central opening and the drive shaft extends through the central opening of the extrusion die and wherein the cutting assembly is rotatably mounted on the drive shaft as it extends through the central opening.

15. The system of Claim 2 wherein the extrusion die contains a central opening and the drive shaft extends through the central opening of the extrusion die and wherein the cutting assembly is rotatably mounted on the drive shaft as it extends through the central opening.

16. The apparatus of Claim 1 wherein the mixing device within the housing cavity is driven by a rotatably mounted drive shaft and the extrusion die contains a central opening through which the drive shaft extends and wherein the cutting assembly is rotatably mounted on the drive shaft where it extends through the central opening.

17. The system of Claim 2 wherein the mixing device within the housing cavity is driven by a rotatably mounted drive shaft and the extrusion die contains a central opening through which the drive shaft extends and wherein the cutting assembly is rotatably mounted on the drive shaft where it extends through the central opening.

18. The apparatus of Claim 1 wherein the extrusion holes are uniformly spaced apart on the face of the extrusion die.

19. The system of Claim 2 wherein the extrusion holes are uniformly spaced apart on the face of the extrusion die.

20. The apparatus of Claim 1 wherein the extrusion holes are arranged in a circular array when the cutting assembly is rotatably mounted.

21. The apparatus of Claim 1 wherein the extrusion holes have a generally circular cross-section.

22. The apparatus of Claim 1 wherein the face of the extrusion die is treated with or is constructed from a material that has a high contact angle with the hydrogel-forming suspension, the material being selected from thermoplastic and thermoset polymers, mineral and glass reinforced polymers, ceramics, foams, minerals, oxides and metals.

23. The system of Claim 2 wherein the face of the extrusion die is treated with or is constructed from a material that has a high contact angle with the hydrogel-forming suspension, the material being selected from

thermoplastic and thermoset polymers, mineral and glass reinforced polymers, ceramics, foams, minerals, oxides and metals.

24. The apparatus of Claim 1 wherein the extrusion die is constructed from an insulating material selected from thermoplastic and thermoset polymers, mineral and glass reinforced polymers, ceramics, foams, minerals, oxides and metals.

5 25. The system of Claim 2 wherein the extrusion die is constructed from an insulating material selected from thermoplastic and thermoset polymers, mineral and glass reinforced polymers, ceramics, foams, minerals, oxides and metals.

10 26. The apparatus of Claim 1 wherein the cutting assembly is selected from pitched turbines and flat turbines.

27. The system of Claim 2 wherein the cutting assembly is selected from pitched turbines and flat turbines.

15 28. The apparatus of Claim 1 wherein the internal pump within the housing cavity is a centrifugal, screw or volumetric displacement pump.

29. The system of Claim 2 wherein the internal pump within the housing cavity is a centrifugal, screw or volumetric displacement pump.

30. The apparatus of Claim 1 wherein the mixing device is selected from the group consisting of mechanical mixers and static mixers.

20 31. The system of Claim 16 wherein the mixing device is selected from the group consisting of mechanical mixers.

32. The apparatus of Claim 1 wherein the apparatus is heated by a heating device.

25 33. The system of Claim 2 wherein at least one of the feed tank, the apparatus, the metering device, the quench station, or the system, independently, are heated by at least one heating device.

30 34. The apparatus of Claim 32 wherein the heating device is selected from thermal mass heaters, traced systems, jacketed systems, and enclosures with circulating hot gases or liquids.

35 35. The system of Claim 33 wherein the heating device is selected from thermal mass heaters, traced systems, jacketed systems, and enclosures with circulating hot gases or liquids.

36. The apparatus of Claim 1 wherein the hydrogel-forming suspension comprises a hydrogel solution and a biocatalyst.

37. The system of Claim 2 wherein the hydrogel-forming suspension comprises a hydrogel solution and a biocatalyst.

38. The apparatus of Claim 36 wherein the biocatalyst is selected from the group consisting of whole cell suspensions, bacterial cells, fungi, algae, yeast cells, plant cells, animal cells, cellular organelles, purified or partially-purified enzyme preparations, and multi-enzyme complexes in appropriate buffer solutions.

5 39. The system of Claim 37 wherein the biocatalyst is selected from the group consisting of whole cell suspensions, bacterial cells, fungi, algae, yeast cells, plant cells, animal cells, cellular organelles, purified or partially-purified enzyme preparations, and multi-enzyme complexes in appropriate buffer solutions.

10 40. A method for producing hydrogel particles, the method comprising the sequential steps of:

- (a) providing a feed station containing a hydrogel-forming suspension,
- 15 (b) metering the hydrogel-forming suspension by a metering device having transfer lines connected to the feed station and receiving hydrogel material therefrom into the hydrogel particle-forming apparatus of Claim 1, the apparatus being at least partially submerged in a quench fluid;
- 20 (c) extruding the hydrogel-forming suspension through the hydrogel particle-forming apparatus into the quench fluid; and
- 25 (d) cutting the extruded hydrogel-forming suspension by the hydrogel particle-forming apparatus into individual hydrogel particles.

41. The method of Claim 40 wherein the hydrogel-forming suspension comprises a hydrogel solution and a biocatalyst.

42. The method of Claim 41 wherein the biocatalyst is selected from the group consisting of whole cell suspensions, bacterial cells, fungi, algae, yeast cells, plant cells, animal cells, cellular organelles, purified or partially-purified enzyme preparations, and multi-enzyme complexes in appropriate buffer solutions.